

**IMAGE BASED CONGESTION DETECTION
ALGORITHMS AND ITS REAL TIME
IMPLEMENTATION**

AHMED NIDHAL KHDIAR

**UNIVERSITI SAINS MALAYSIA
2015**

**IMAGE BASED CONGESTION DETECTION
ALGORITHMS AND ITS REAL TIME
IMPLEMENTATION**

by

AHMED NIDHAL KHDIAH

**Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy**

September 2015

DEDICATION

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

... نَرْفَعُ دَرَجَاتٍ مِّنْ نَّشَأٍ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ ﴿٧٦﴾ سورة يوسف

Without Allah SWT blessing and guidance, my work would never have been possible

My supervisors Assoc. Prof. Dr. Umi Kalthum binti Ngah, Prof. Dr Widad Ismail

My great family, my dearest parents, my beloved wife, my sweet daughter Dania

My brother and sisters

To those who sacrificed their lives for all of us to live peacefully

ACKNOWLEDGMENT

My profound gratitude to Almighty Allah for the blessing, protection, strength and patience in completing my PhD research.

I wish to express my sincere appreciation and honor to some great people that have tirelessly been a source of encouragement and help, also for their invaluable cooperation and contributions in my study and in the completion of this work. From them, I learned the knowledge, patient, wisdom, humility and also how to gain my goals.

I would like to express my deep gratitude to my supervisor, Assc. Prof Dr. Umi Kalthum binti Ngah and my co-supervisor Prof Dr Widad Ismail for their encouragement, assistance, understanding and guidance throughout the period of my research. It is not often that one finds such great advisors who always find the time for listening to the little problems and roadblocks that unavoidably crop up in the course of performing research. Their technical and editorial advices were essential to the completion of this thesis. It was an honor to work with them.

I would like to extend my gratitude to all members of staff of School of Electrical and Electronic Engineering, Universiti Sains Malaysia, especially school dean Prof Dr Mohd Zaid Bin Abdullah, who by one way or the other have contributed to the success of this work. I am also so grateful to all my colleagues from Universiti Sains Malaysia, for their encouragement and support. Special thanks to my colleague Girish for his help and support. I also wish to express my token of appreciation to the technical staff in CEDEC Lab USM for their kind assistance during my test and experiment work. I would like to express my thanks to the technical staff in communication Lab and AIDL

lab who were very friendly and cooperative, Miss Mastika Suhaila, En.Abdul Latip and Pn. Zammira binti Khairuddin.

I would like to thank my employer University of Kufa and the (Ministry of higher educations and scientific researchers-Iraq) for giving me the opportunity to seek for this PhD degree. My deepest appreciation to all my friends who supported me and continuously encouraged me.

My warmest feeling is addressed to my parents, for their support, prayers and encouragement during the whole time of my study. I do not think I will be able to complete this work without them. Special thanks to my beloved wife and my sweet daughter Dania for their support, understand, care and love during the hard and easy times. I am also grateful for my brother and sisters for believing in me to complete this work successfully. I am forever indebted for all of you.

I would like to express my gratitude to the wonderful Malaysian people for their hospitality and for giving their kind help to me during my stay in Malaysia.

TABLE OF CONTENTS

	Page
DEDICATION	i
ACKNOWLEDGMENT	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	viii
LIST OF FIGURES	x
LIST OF ABBREVIATIONS	xvi
LIST OF PUBLICATIONS	xviii
ABSTRAK	xix
ABSTRACT	xxi
CHAPTER 1	1
INTRODUCTION	1
1.1 General View and Background.....	1
1.2 Problem Statements	7
1.3 Research Objectives	8
1.4 Scope of the Work	8
1.5 Thesis Outline.....	9
CHAPTER 2	11
LITERATURE REVIEW	11
2.1 Introduction	11
2.2 Traffic Congestion Detection and Estimation	11
2.2.1 Non-Image Processing Systems	12
2.2.2 Image Processing Techniques	21

2.2.3	Image Segmentation Using Watershed Algorithm	35
2.3	Software-Defined Radio	37
2.3.1	SDR Implementations	40
2.4	SFF SDR Development Platform Main Components	43
2.4.1	SDR Hardware	47
2.4.2	Software Environment of SDR	53
2.5	The Limitations and Advantages of the Previous Studies	57
2.6	The Receiver Operating Characteristics Curves as an Evaluation Tool....	63
2.7	Summary.....	67
CHAPTER 3		68
METHODOLOGIES		68
3.1	Introduction	68
3.2	System diagram	68
3.3	System infrastructure.....	70
3.3.1	Image Processing Stage	73
3.4	Summary.....	99
CHAPTER 4		100
SDR Implementation		100
4.1	Introduction	100
4.2	Real Time Implementation	101
4.3	Hardware- The SDR	101
4.4	Software- The SDR	101
4.5	Preparing Data for Transmission.....	105
4.6	FSK Mod/Demod	105

4.7	Receiving and Storing Data.....	108
4.8	Transmitting Image to Remote Station.....	108
4.8.1	DSP Part	109
4.8.2	FPGA Module	111
4.8.3	Image Transceiver Performance	114
4.9	Summary.....	137
CHAPTER 5		138
RESULTS AND ANALYSIS.....		138
5.1	Introduction	138
5.2	Detecting Traffic Congestion:	138
5.2.1	Database	138
5.2.2	Detecting Traffic States using Modified Watershed Algorithm	139
5.2.3	Detection Based on the Features of the Vehicles	145
5.2.4	Backlight Detection	146
5.2.5	Backlight Pairing	148
5.2.6	Congestion Estimation	160
5.3	Results and Analysis.....	160
5.4	Summary.....	165
CHAPTER 6		166
CONCLUSIONS AND FUTURE WORKS		166
6.1	Summary and Conclusion.....	166
6.2	Limitations of the Study	167
6.3	Future Works	168
REFERENCES.....		169

APPENDIX A 187

A.1 Hardware assembly 187

A.2 Software Installation Procedure 188

APPENDIX B 194

APPENDIX C 197

APPENDIX D 208

LIST OF TABLES

	Page
Table 2.1: SDR Forum`s tier definitions (Ko <i>et al.</i> , 2005)	39
Table 2.2: Advantages of Software-Defined Radio (Harrington <i>et al.</i> , 2004)	44
Table 2.3: Software Defined Radio Attribute (Lyrtech, 2009)	47
Table 2.4: Hardware and software requirements (Lyrtech, 2009)	49
Table 2.5: Digital Processing Module Attributes (Lyrtech, 2009).....	50
Table 2.6: Data Conversion Module Attributes (Lyrtech, 2009)	51
Table 2.7: RF Module Attributes (Lyrtech, 2009)	52
Table 2.8: SDR software requirements (Lyrtech, 2009)	54
Table 2.9: Summary of the reviewed SDR systems.....	56
Table 2.10: Related researchers	57
Table 2.11: Proposed System Features Comparison to other related works. X-considered, O-not considered	62
Table 2.12: Communication system comparison to other related works. X-considered, O- not considered	63
Table 4.1: FPGA I/O Interfaces and corresponding MBDK FPGA Blocks	112
Table 4.2: PSNR values for several images	132
Table 4.3: Device Utilisation Summary of fully designed system.....	133
Table 4.4: Timing Summary of fully designed system.....	133
Table 4.5: FPGA Logic Utilisation and Logic Distribution (Map) based on fully designed system	134
Table 4.6: FPGA Logic Utilisation based on placed and routed (PAR) based on fully designed system	136

Table 5.1: Congestion detection accuracy using vehicle’s features method (backlights pair method) 161

Table 5.2: Congestion detection accuracy using modified watershed method 162

LIST OF FIGURES

	Page
Figure 1.1: Vehicle ownership (person per vehicle) (MIORS, 2014).....	2
Figure 1.2: CO ₂ emission VS average speed (Barth & Boriboonsomsin, 2009)	3
Figure 1.3: CCTV control room.....	8
Figure 2.1: Number of registered vehicles per year in Malaysia (JPJ, 2014).....	12
Figure 2.2: Intersection locations (red signs) (Ying-nian & Qi-fu, 2010)	15
Figure 2.3: VANET system.....	16
Figure 2.4: Tail vehicle communicating RSU (Xu <i>et al.</i> , 2012).....	17
Figure 2.5: Single vehicle communication (Wang & Tsai, 2013)	18
Figure 2.6: Traffic count spots related with cellular antennas (Demissie <i>et al.</i> , 2013) ..	20
Figure 2.7: Phone position estimator (Chandrasekaran <i>et al.</i> , 2011).....	21
Figure 2.8: Vehicle detection from an aerial view (Hinz, 2003)	22
Figure 2.9: Detection of rear view and backlights. a) Original image. b) Detection results (Ye <i>et al.</i> , 2013)	23
Figure 2.10: Steps of traffic states detection proposed by (Li <i>et al.</i> , 2013).....	25
Figure 2.11: traffic congestion detection system with future fusion based track initiation technique proposed by (Zhang <i>et al.</i> , 2013).....	27
Figure 2.12: Framework for detecting moving vehicles (Gangodkar <i>et al.</i> , 2012).....	29
Figure 2.13: Vehicle detection from an in-car video (Jazayeri <i>et al.</i> , 2011).....	30
Figure 2.14: Detected vehicles using method in (Cheon <i>et al.</i> , 2012).....	31
Figure 2.15: Backlight detection using method proposed by (O'Malley <i>et al.</i> , 2010)....	31
Figure 2.16: Selected features in image strips (Zheng & Liang, 2009)	32
Figure 2.17: Test bed Set-up for Receiver Performance Evaluation (Xu <i>et al.</i> , 2006)...	41

Figure 2.18: SDR BERT set-up (Ekhlas, 2011).....	41
Figure 2.19: OFDM transmitter modules (Gutierrez <i>et al.</i> , 2013).....	43
Figure 2.20: Communication system top model.....	45
Figure 2.21: The physical setup - completely built and connected SDR.....	46
Figure 2.22: SDR modules (Lyrtech, 2007a).....	50
Figure 2.23: VPSS port (Lyrtech, 2007a).....	53
Figure 2.24: Confusion matrix and common performance metrics calculated from it (Fawcett, 2006).....	65
Figure 2.25: Interpretation of an ROC curve.....	66
Figure 3.1: The development of the overall system.....	69
Figure 3.2: Depicts the whole system infrastructure which consists of image processing stage and communication stage.....	70
Figure 3.3: Image processing stage flow chart.....	72
Figure 3.4: Camera position.....	75
Figure 3.5: Watershed algorithm flow diagram.....	79
Figure 3.6: Watershed Min and Max regions(Bieniecki <i>et al.</i> , 2003).....	80
Figure 3.7: Traffic image and its watershed equivalent image.....	80
Figure 3.8: Detecting Congestion using vehicle's backlights.....	84
Figure 3.9: HSV color representation (Cucchiara <i>et al.</i> , 2001).....	86
Figure 3.10: Original image and its HSV equivalent.....	87
Figure 3.11: Vehicles backlights vanishing in horizon.....	90
Figure 3.12: Regions according to distance from camera.....	90
Figure 3.13: a) Objects centroids b) Distance between objects.....	91
Figure 3.14: Angles between objects.....	91

Figure 3.15: Corrected angles between objects	92
Figure 3.16: Result of pairing before and after object single pairing	92
Figure 3.17: Approximate vehicles spacing.....	93
Figure 3.18: Congestion Estimation methodology flow diagram	96
Figure 3.19: Congestion counter	97
Figure 3.20: Antenna power saving	98
Figure 4.1 : Transmitting/ receiving image block diagram.....	103
Figure 4.2: Connection between DSP and FPGA	104
Figure 4.3: Reading data and transmitting it to FPGA.....	105
Figure 4.4: Data modulation using DDS Compilers	106
Figure 4.5: Data Demodulator.....	107
Figure 4.6: Demodulator down sampler	107
Figure 4.7: Data receiving and storing.....	108
Figure 4.8: The DSP module.....	110
Figure 4.9: FSK transceiver and VPSS ports	113
Figure 4.10: Experimental setup	114
Figure 4.11: SDR setup with normal distance between transmitter and receiver	115
Figure 4.12: SDR setup with 50cm distance between transmitter and receiver	115
Figure 4.13: Simulation module.....	117
Figure 4.14: Modulated and Demodulated signals	118
Figure 4.15: RF module settings	119
Figure 4.16: Transmitted signal	120
Figure 4.17: Relation between received signal power and distance between antennas	122
Figure 4.18: Bit loss percentage vs distance between antennas.....	122

Figure 4.19: The gap between 0 and 1 power levels..... 123

Figure 4.20: Original image to be transmitted and received via SDR 124

Figure 4.21: Original and received images for 20cm distance between SDR antennas 124

Figure 4.22: Original and received images for 150cm distance between SDR antennas
..... 124

Figure 4.23: Original and received images for 20cm distance between SDR antennas 125

Figure 4.24: Original and received images for 150cm distance between SDR antennas
..... 125

Figure 4.25: Original and received images for 150cm distance between SDR antennas
..... 125

Figure 4.26: Original and received images for 20cm distance between SDR antennas 126

Figure 4.27: Original and received images for 20cm distance between SDR antennas 126

Figure 4.28: Original and received images for 150cm distance between SDR antennas
..... 126

Figure 4.29: Original and received images for 20cm distance between SDR antennas 127

Figure 4.30: Original and received images for 150cm distance between SDR antennas
..... 127

Figure 4.31: Original and received images for 20cm distance between SDR antennas 127

Figure 4.32: Original and received images for 150cm distance between SDR antennas
..... 128

Figure 4.33: Original and received images for 20cm distance between SDR antennas 128

Figure 4.34: Original and received images for 150cm distance between SDR antennas
..... 128

Figure 4.35: Original and received images for 20cm distance between SDR antennas 129

Figure 4.36: Original and received images for 150cm distance between SDR antennas	129
.....	
Figure 4.37: Original and received images for 20cm distance between SDR antennas	129
Figure 4.39: Original and received images for 150cm distance between SDR antennas	130
.....	
Figure 4.38: Original and received images for 150cm distance between SDR antennas	130
.....	
Figure 4.40: Original and received images for 20cm distance between SDR antennas	130
Figure 5.1: Original image and its grey level equivalent	139
Figure 5.2: a) Extended maximum image b) Extended minimum image	140
Figure 5.3: Images after morphological operation a) Extended maximum image b)	
Extended minimum image	141
Figure 5.4: Merging maximum and minimum images	142
Figure 5.5: Merged image after morphological operations	143
Figure 5.6: Congested road detected using modified watershed algorithm	144
Figure 5.7: Clear road detected using modified watershed algorithm	145
Figure 5.8: Scenes during day and night	146
Figure 5.9: Original image and its equivalent HSV image (saturation components only)	147
.....	
Figure 5.10: Original image at night scene with its HSV equivalent (Value components only)	148
.....	
Figure 5.11: a) Grey equivalent image b) Normalized grey image	149
Figure 5.12: a) Grey image after morphological operation b) Objects centroids	150
Figure 5.13: Candidate backlights	151

Figure 5.14: Detected vehicles.....	152
Figure 5.15: Results of vehicle detection.....	153
Figure 5.16: Results of vehicle detection.....	154
Figure 5.17: Results of vehicle detection.....	155
Figure 5.18: Results of vehicle detection.....	156
Figure 5.19: Results of vehicle detection during night	157
Figure 5.20: Results of vehicle detection during night	158
Figure 5.21: Results of vehicle detection during night	159
Figure 5.22: ROC curve for detection method based on features of the vehicles (backlights pair method)	163
Figure 5.23: ROC curve for the modified watershed algorithm	164

LIST OF ABBREVIATIONS

ADC	Analogue to Digital Converter
AOG	AND-OR Graph
BSDK	Board Software Development Kit
CCTV	Closed-Circuit Television
CMYK	Cyan, Magenta, Yellow, and Key
DAC	Digital to Analogue Converter
DCM	Data Conversion Module
DDS	Direct Digital Synthesizers
DSP	Digital Signal Processing
FPGA	Field-Programmable Gate Array
FSK	Frequency-Shift Keying
GPS	Global Positioning System
GSM	Global System for Mobile communications
HSV	Hue, Saturation, and Value
MANET	Mobile Ad Hoc Network
MBDK	Model-Based Development Kit
MRF	Markov Random Filter
OD	Original Destination
OFDM	Orthogonal frequency-division multiplexing
PLL	Phase Lock Loop
PSK	Phase-Shift Keying

RF	Radio Frequency
RGB	Red, Green, and Blue
RSU	Road Side Units
SDR	Software-Defined Radio
SFF	Small Form Factor
SoC	System-on-Chip
V2I	Vehicle to Infrastructure
V2V	Vehicle-to-Vehicle
VANET	Vehicular ad hoc network
VPBE	Video Processing Back End
VPFE	Video Processing Front End
VPSS	Video Processing Subsystem
XML	Xtensible Markup Language

LIST OF PUBLICATIONS

Khdiar, A. N., Kalthum bt Ngah, U., & Ismail, W (2011). *Traffic Congestion Detection Using Modified Watershed Algorithm*. Paper presented at the 3rd postgraduate colloquium school of Electrical and Electronics Engineering. University Sains Malaysia. EEPC, 2011.

Khdiar, A. N., Kalthum bt Ngah, U., & Ismail, W. (2013). Development and implementation of embedded wireless traffic congestion system using wireless image mesh sensor network technology. *IETE Journal of Research*, 59(5), 648-653.

Khdiar, A. N., Kalthum bt Ngah, U., & Ismail, W (2013). *Traffic congestion detection using vehicles' features*. Paper presented at the 4th postgraduate colloquium school of Electrical and Electronics Engineering. University Sains Malaysia. EEPC, 2013.

Nidhal, A., Ngah, U. K., & Ismail, W. (2014, 3-5 June 2014). *Real time traffic congestion detection system*. Paper presented at the Intelligent and Advanced Systems (ICIAS), 2014 5th International Conference on.

ALGORITMA PENGESANAN KESESAKAN BERDASARKAN IMEJ DAN PELAKSANAANNYA SECARA MASA NYATA

ABSTRAK

Dalam tahun-tahun kebelakangan ini, pengurusan trafik pintar telah menempa banyak bidang-bidang baharu dan dilengkapi dengan baharu. Salah satu bidang penting yang memberi kesan secara langsung dalam kehidupan kita ialah sistem amaran kesesakan lalu lintas iaitu satu sistem lengkap yang mampu mengesan kesesakan dan pihak-pihak berkaitan dalam keadaan berjaga-jaga bagi menjimatkan masa, bahan bakar dan tenaga manusia. Kaedah-kaedah terkini memerlukan pengetahuan sebelumnya tentang keadaan lalulintas atau diperlukan masa untuk membuahkan hasil atau satu infrastruktur yang amat besar diperlukan untuk melaksanakan sistem itu. Namun begitu, usaha yang dilaksanakan secara tiada dalam masa nyata. Kebanyakan kajian semasa berkaitan pemprosesan imej untuk implementasi sebenar telah didapati tidak begitu boleh dipercayai kerana sama ada hasilnya kurang jitu ataupun ia tidak mampu dilaksanakan secara masa nyata. Sistem yang dicadangkan bertujuan untuk mencari cara pengesanan kesesakan baru yang mempunyai kejituan tinggi dan pemprosesan secara masa nyata, ia juga bertujuan untuk menunjukkan menghantar/menerima proses untuk penghantaran imej menggunakan *Software Defined Radio*. Sistem ini menawarkan satu pengesanan lengkap dan rangkaian penggera yang menangkap satu imej keadaan jalan raya, menentukan sama ada kesesakan lalu lintas berlaku dan akhirnya melaporkan keputusan secara wayarles kepada badan-badan pengurusan trafik bertindak dan memberitahu orang ramai supaya mengelak kawasan sesak dalam masa nyata. Satu

kaedah yang boleh dipercayai dan cepat mengesan kesesakan lalu lintas lelah dicadangkan. Kaedah ini pengesanan kenderaan dengan menggunakan algoritma ciri pasangan cahaya belakang dan algoritma *Watershed* terubahsuai. Hasil keputusan daripada algoritma dihantar dan diterima secara wayarles menggunakan platform SFFSDR, termasuk penggunaan RF, FPGA, dan modul-modul DSP untuk jarak berubah-ubah. Perolehan sistem menunjukkan pengesanan dengan ketepatan 98-98.8% penggunaan masa selama 3 saat menunjukkan kesesuaiannya bagi pelaksanaan masa nyata. Sistem wayarles telah diuji menggunakan jarak berbeza-beza antara antena-antena SDR. Penerimaan kuasa, peratus kehilangan bit dan PSNR untuk imej yang diterima telah diperolehi. Keputusan yang diperolehi menunjukkan satu PSNR 35 dB untuk jarak normal antara antena-antena (20cm) SDR dan 7 dB untuk 150cm, manakala bit-bit mula terhapus menjelang jarak 200cm.

IMAGE BASED CONGESTION DETECTION ALGORITHMS AND ITS REAL TIME IMPLEMENTATION

ABSTRACT

In recent years, intelligent traffic management have included many new fields and features. One of the important fields which directly affect our life is the traffic congestion alert system i.e. a complete system which is able to detect congestion and alert concerned parties to save time, fuel and man power. Recent methods in congestion detection need prior knowledge about the road or several minutes are taken to produce results or a huge infrastructure is needed to implement the system, even then, not in real time. Most of the current studies in image processing are not reliable for real implementation because they either lack accuracy or do not work in real time. The proposed system aims to find a new congestion detection method that has high accuracy and having real time processing time, also it aims to demonstrate the transmit/receive process for image transmission using Software Defined Radio. The proposed system offers a complete detection and alert network that captures an image of the road situation, determine whether the road is congested or clear and finally report the results wirelessly to the traffic management bodies to take action and inform people to avoid the congested areas in real time. The proposed system uses a fast and reliable method to detect traffic congestions. The methodology includes vehicle detection by using backlight pairing feature algorithm and modified Watershed algorithm. The results returned by the algorithms are transmitted and received wirelessly using the SFFSDR platform, including the use of RF, FPGA, and DSP modules for variable distances. The

system shows an accuracy of detection up to 98-98.8% with time consumption of up to 3 seconds which make it feasible for real time implementation. The wireless system has been tested using different distances between SDR antennas. The received power, bit loss percentage and PSNR for the received image have been obtained, results shows a 35dB PSNR for normal distance between SDR antennas (20cm) and 7dB for 150cm, while bits are totally lost when reaching 200cm.